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Assessment of Magnetic Resonance Imaging Safety: Allied Health Professional Clinical Competence

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A thesis

presented to

the faculty of the Department of Allied Health Sciences

East Tennessee State University

In partial fulfillment

of the requirements for the degree

Master of Science in Allied Health

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by

Tiffany Houser

May 2019

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Dr. Randy L. Byington

Dr. Susan B. Epps

Keywords: MRI safety, safety training, MRI safety survey, MRI hazards

ABSTRACT

Assessment of Magnetic Resonance Imaging Safety: Allied Health Professional Clinical Competence

by

Tiffany H. Houser

Magnetic resonance imaging is a major advancement in the diagnostic imaging field. Most patients can tolerate an MRI however, there are some who are unable to complete a lengthy scan while lying completely still without sedatives or anesthesia. Non-MRI healthcare providers are trained to use equipment that is “unsafe” in the MRI suite due to the strong magnetic field. Staff who are not fully knowledgeable and trained in MRI safety measures can endanger staff and patients.

The purpose of this study was to determine the knowledge level of non-MRI healthcare providers regarding safety risks associated with MRI and to determine their level of satisfaction regarding the MRI safety training they received. This study concluded that non-MRI healthcare providers are knowledgeable about most of the safety hazards. They are satisfied with annual training but would like more in-depth material added to their current learning modules.

DEDICATION

I dedicate this thesis to my family and friends who have encouraged me and never stopped believing in my ability to accomplish such a large feat.

To my husband, Dwayne, you have provided unwavering love and support during the ups and downs of this tedious process. You believed in me and pushed me to pursue something I would have never done on my own and I am very blessed to call you my husband.

To mom, dad, Wayne, and Ruth: you all gave me the support and encouragement to further my education and never doubted that I could do it. Your love and support carried me through, and I hope that I will always make you proud to call me your daughter.

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CHAPTER 1

INTRODUCTION

In 1895, radiographic imaging was discovered in Wurzburg, Germany by professor Wilhelm Conrad Roentgen. Within weeks, the x-ray was being used in the field of dentistry (Sansare, Khanna, & Karjodkar, 2011). In the following months, x-rays were used to diagnose diseases and broken bones and to determine the location of bullet fragments retained from the battlefield (Linton, 1995; Thomas, 2007). Over the past 122 years, the addition of imaging modalities such as ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine, positron emission tomography (PET), radiation therapy, mammography, bone density, and interventional radiography (IR) have transformed the field of radiography and health care. Initially, the only means of diagnosis by radiography required the use of ionizing radiation, which is harmful to both the patient and the healthcare provider. Today, there are two modalities that use non-ionizing radiation, ultrasonography and MRI. Although non-ionizing, ultrasonography and MRI still present potential harm to the patient and healthcare provider and therefore, additional training is required.

Magnetic resonance imaging (MRI) has proven to be clinically useful because the MRI signal provides higher spatial resolution and tissue contrast differentiation than is available through any other imaging modality (Bolus, George, Washington, & Newcomer, 2009). According to Giroletti and Corbucci (2005), "[MRI] images are able to show up various functional structures very clearly, and in some respects are superior to those yielded by other techniques" (p. 5). MRI is available today in both large and small communities nationwide due to rapid technological advances in magnet technology, gradient coil design, radiofrequency technology, and computer engineering (Zhuo & Gullapalli, 2006). According to Lakrimi et al. (2012),

> Almost all the tissues in the body [can] be noninvasively and routinely scanned, enabling the diagnosis of tumours, tendonitis, stroke, multiple sclerosis, infections of the brain, spine and joints, visualisation of torn ligaments, or shoulder injuries, brain trauma (bleeding or swelling), and evaluation of bone tumours, cysts, bulging/herniated discs, structure of the heart or aorta or masses in soft tissue (p. 1).

Unlike other imaging modalities, data is acquired by using electromagnetic waves to “[create] an oscillating magnetic field that is transmitted into the patient, absorbed by the body and transmitted out” (Guterl, 2001, p. 23). Because the radiofrequency energy is non-ionizing, the American College of Radiology approves patients who are pregnant to undergo an MRI during any trimester (Koetcha et al., 2016).

In conjunction with radio frequency current, an MRI scanner uses a magnetic field to aid in the production of images. Magnetic field strengths vary among different types of scanners and extend well beyond the unit itself, despite the latest shielding technology (Mcrobbie, 2012). Field strengths of today’s MRI scanners, upwards of 60,000 times greater than the earth’s magnetic field, have a strong attractive force with the ability to draw ferrous (highly magnetic) objects (i.e. scissors, wheelchairs, stretchers) into the center of the machine, thus creating possible damage to the equipment and injury to anyone in its path (Gilk, 2006). The force also has the potential to create torque or migration of an implanted medical device if it has not been cleared for use in the MRI scanner. Other potential hazards include skin burns from devices or medication patches left on the patient, asphyxiation from spontaneous release of cryogenic gases and electrocution from implanted medical devices with electrical wires (Kanal et al., 2013). In addition to injury or death, ferrous objects mistakenly brought into the MRI scan room can result in equipment damage, costing on average $43,172 per occurrence, and this does not include the additional costs of downtime and lost revenue (U. S. Department of Veterans Affairs, n.d.).

Most patients can tolerate an MRI; however, the procedure is more challenging for pediatric, claustrophobic, and physically and emotionally distressed patients. Due to their inability to remain immobile during the procedure, the use of sedation or anesthesia may be indicated though respiratory depression and hypoxemia are of great concern during a sedated procedure. Moreover, injured and critically ill patients can experience central nervous system or cardiopulmonary complications (Medical Advisory Secretariat, 2003).

The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) requires physiologic monitoring during the use and recovery of sedatives and anesthesia (Medical Advisory Secretariat, 2003).

> Factors such as increasing magnet strength, greater utilization for emergent/trauma cases, wider patient dependence on medical devices or implants that may be contraindicated for MR exams, larger numbers of sedation/general anesthesia patients, and interventional applications from image-guided biopsies to intraoperative imaging are all perceived to ratchet up the opportunities for mishaps (Gilk, 2007, p. 30).

To that end, keeping patients and staff members safe has been an ongoing issue since the 1980s, particularly as healthcare provider traffic has increased in the MRI suite. “Although exposure to magnetic fields may be safe, unsafe practices around the magnet have led to many accidents, some of them fatal” (Zhuo & Gullapalli, 2006, p. 291). The issue of MRI safety had not garnered much attention until the 2001 incident in which a six-year-old child died while undergoing an MRI. He suffered irreparable brain damage when a ferrous oxygen tank brought into the room by a respiratory therapist became a projectile, traveling at 20-30 feet per second

(Landrigan, 2001). According to Hemingway and Kilfoyle (2013), "Most healthcare workers do not understand that an MRI magnet is always on and that turning off the magnet when it is not in use is dangerous and cost-prohibitive" (p. 511).

To help prevent future incidents, the International Magnetic Resonance Safety Committee implemented additional safety precautions. A "zone system" was created with strict access in mind to limit the number of adverse events in an MRI suite. In any given MRI department, there are four zones. Zone 1 consists of areas freely accessible to the public. Zone 2 is typically an area for greeting patients and performing the safety screening process; entrance is permitted to all hospital employees through badge access. Zone 3 is the technologists' work area and can be entered by badge access granted only to MRI personnel. At this point, all individuals must be visually and verbally screened for biomedical implants and contraindicated items on their body; once cleared, they are permitted to enter under technologist supervision. Zone 4 is the scan room and can only be entered by the MRI technologist or with technologist supervision. All zones are clearly marked and constructed to warn individuals entering the department (Westbrook, Roth, & Talbot, 2011). Additionally, the use of ferromagnetic detection systems has increased. These systems are installed at the entrance to Zone 3 or 4 and produce an audible and visual alarm when a ferrous object is near. Although these precautionary measures have aided in decreasing the number of adverse events, they should not be a substitute for conventional screening methods (Shellock & Karacozoff, 2013).

One final method aimed at reducing accidents is the inclusion of learning modules for facility employees. The American College of Radiology (ACR) recommends all employees working in Zone 3 complete a live lecture or prerecorded presentation approved by the facility MRI medical director and complete a post-test (Kanal et al., 2013). According to Westbrook, Roth, and Talbot (2013), it has become the accepted standard at most imaging sites to provide hospital-wide MRI safety training. In addition to radiographers, radiologists, and radiology nurses, it is advised that ancillary staff who work indirectly with MRI, including receptionists, patient transporters, maintenance workers, and housekeeping staff also receive annual training. Fire, emergency, and police personnel also have the potential for exposure and should be educated about the hazards of the static magnetic field.

Statement of the Problem

In order to provide imaging services to critically ill patients, the MRI technologist must depend upon ancillary staff. Additionally, it is difficult to image critically ill patients without the assistance of ancillary staff. Non-MRI healthcare providers are trained to use products and equipment that are deemed “MR Unsafe,” such as oxygen tanks, IV pumps, and physiological monitors. Therefore, inviting staff who are not fully knowledgeable and trained in MRI safety measures into the MRI suite can bring devastating consequences, such as injuries and possibly death.

Purpose of the Study

The purpose of this study was to determine the knowledge level of non-MRI healthcare providers regarding safety risks associated with MRI. Additionally, the study was intended to determine the non-MRI healthcare provider’s level of satisfaction regarding the MRI safety education training they received.

Significance of the Study

Ancillary staff play a vital role by assisting the MRI technologist with completion of an imaging procedure for critically ill patients. To maintain a safe environment, MRI technologists need to understand how much ancillary staff know about MRI safety and to ascertain their satisfaction with the MRI safety training they receive. Due to the extensive amount of safety training MRI technologists receive, they may underestimate the level and quality of education and training of non-MRI healthcare providers.

The results of this study can be used to inform health care administration of any deficiencies in their MRI safety training for non-MRI healthcare providers. Results of the study can provide information to improve the amount or frequency of training provided to staff members. Likewise, the data may indicate the need for content modification to improve the quality of the training.

Research Questions

The following questions guided this research:

1. What is the knowledge level of non-MRI healthcare providers regarding MRI safety?
2. What is the knowledge level of non-MRI healthcare providers regarding safety hazards in MRI?
3. Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?
4. Is there a difference in MRI safety knowledge level among providers based on length of employment?

Delimitations

1. The study was delimited to participants who are required to enter MRI Zones 3 or 4. Some groups of non-MRI healthcare providers are never required to enter either zone and were purposefully excluded from the study.

2. Only non-MRI healthcare providers from an inpatient setting were included. Outpatient settings were not studied as they typically do not require the use of ancillary staff to assist with MRI since the patients are not critically ill.

Limitations

1. Some participants may have recently completed their MRI educational training and therefore the retained material was fresh in their mind, leading to a more accurate knowledge base.
2. Some participants may not provide detailed feedback.

Assumptions

I assumed that the participants chosen were trained and certified to practice in their respective profession. I also assumed that participants received some MRI safety training. Moreover, I assumed that participants answered questions honestly and to the best of their ability.

Operational Definitions

Bone densitometry: A radiology subspecialty in which a radiographic bone density test is performed to measure strength and density of bones (John Hopkins Medicine, n.d.).

Cryogenic gases: Liquid helium that resides inside the MRI scanner. The liquid is chilled to -450 degrees Fahrenheit (Gilk, 2006) to cool the magnets and reduce the amount of electricity needed.

Computed tomography (CT): Recording of a predetermined plane in the body by use of an x-ray beam that is measured by a scintillation counter, recorded on a magnetic disk, and then processed by a computer for display on a cathode ray tube (Adler & Carlton, 1994).

Interventional radiology (IR): A sub-specialty of radiology utilizing minimally-invasive image-guided procedures to diagnose treat diseases in nearly every organ system (John Hopkins Medicine, n.d.)

Ionizing radiation: A form of energy that acts by removing electrons from atoms and molecules of materials that include air, water, and living tissue (Centers for Disease Control and Prevention, 2015).

Magnetic resonance imaging: The process of using a magnetic field and radiofrequencies to create sectional images of the body (Adler & Carlton, 1994).

Mammography: Radiography of the breast (Adler & Carlton, 1994).

MR safe: Items that are nonconducting, nonmetallic and nonmagnetic. Objects, such as plastic, that pose no known hazard in all MR environments (Clauson, 2012).

MR unsafe: Items that are highly magnetic, such as scissors, and pose a hazard in all MR environments (Clauson, 2012).

MR conditional: Items that pose no known hazard in a specified MR environment with specified conditions (Clauson, 2012). Any item parameter that affects safety issues, such as thermal injury, induced currents/voltages, electromagnetic compatibility, neurostimulation, acoustic noise, interaction among devices, and the safe functioning of the device or MR system should be described and labeled as “Conditional” (Shellock, Woods & Crues, 2009).

Non-ionizing radiation: A series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Non-ionizing radiation includes the spectrum of ultraviolet (UV), visible light, infrared (IR), microwave (MW), and radiofrequency (RF) (United States Department of Labor, n.d.).

Non-MRI healthcare provider: Health care providers are individuals who provide medical or health services, and any other person furnishing healthcare services or supplies (Social Security Administration, n.d.). For the purpose of this study, non-MRI healthcare providers are individuals providing medical or health services who are not employed in the MRI department. These individuals include, but are not limited to, nursing, respiratory therapy, patient transportation, physicians, physician assistants, and environmental services technicians.

Nuclear medicine: A branch of radiology that involves the introduction of radioactive substances into the body for both diagnostic and therapeutic purposes (Adler & Carlton, 1994).

Positron emission tomography (PET): A radiologic procedure that uses a radioactive substance to evaluate the metabolism of a particular organ or tissue (John Hopkins Medicine, n.d.).

Quench: Sudden loss of superconductivity of the magnet coils that results in the magnetic field being stifle (Westbrook, Roth & Talbot, 2011).

Radiation therapy: A branch of radiology involved in the treatment of disease by means of x-rays or radioactive substances (Adler & Carlton, 1994).

Satisfied: Generally defined as “to make happy or contented” and “to meet the needs of” (Merriam-Webster, n.d.). For the purpose of this study, satisfied is defined as the employee’s perception that they have received adequate training and education to maintain a safe environment of care.

Ultrasonography: Visualization of deep structures of the body by recording the reflections of pulses of ultrasonic waves directed into the tissue (Adler & Carlton, 1994).

CHAPTER 2

LITERATURE REVIEW

History of the X-ray

In 1895, Wilhem Conrad Roentgen, a German professor at the University of Wurzburg, was working with a cathode-ray tube in his laboratory when he made the discovery of the "x-ray." Roentgen noticed a green fluorescent light being generated and realized that this "ray" could pass through solid objects but not metal. The first radiographs were taken of his wife's hand (Reed, 2011). Additional work of many physicists and physicians over several decades resulted in gradual improvements to Roentgen's discovery (Rossi & Kellerer, 1995).

Fourteen days following Roentgen's announcement of his discovery, the first dental radiograph was taken by Freidrich Otto Walkhoff, who would later establish the world's first dental roentgenological laboratory (Sansare, Khanna, & Karjodkar, 2011). Within six months of Roentgen's announcement, radiographs were being produced on the battlefield during the Abyssinian War to locate bullets and broken bones in injured soldiers (Thomas, 2007). Additionally, surgeons began to study the human body by performing radiographs on Viennese mummies (Assmus, 1995). A chest x-ray became the standard method for diagnosing tuberculosis and eventually resulted in the first x-ray screening efforts. Using x-ray to diagnose the disease helped to isolate those who were infected and prevent the spread of the disease to family members (Linton, 1995). Soon, dentists in Germany and England were producing radiographs of teeth. However, exposures were lengthy, ranging from 10 to 25 minutes (Panchbhai, 2015). By 1896, one of the first documented oncologic radiation applications was used to treat a possible gastric lymphoma (Lischalk et al., 2016). Today, x-ray therapy has become the principle mode of radiological cancer treatment (Rossi & Kellerer, 1995).

Dangers of Ionizing Radiation

"Ionizing radiation is energy in the form of waves or particles that has enough force to remove electrons from atoms" (United States Environmental Protection Agency, 2007, p. 1). According to the United States Environmental Protection Agency (EPA) (2007):

> Radiation affects people by depositing energy in body tissue, which can cause cell damage or cell death. In some cases there may be no noticeable effect. In other cases, the cell may survive but become abnormal, either temporarily or permanently. Additionally, an abnormal cell may become malignant. Both large and small doses of radiation can cause cellular damage. The extent of the damage depends upon the total amount of energy absorbed, the time period and dose rate of the exposure, and the particular organs exposed. By damaging the genetic material (DNA) contained in the body's cells, radiation can cause cancer. Damage to genetic material in reproductive cells can cause genetic mutations that can be passed on to future generations. In rare occurrences where there is a large amount of radiation exposure, sickness or even death can occur in a limited amount of hours or days (p. 11).

Early x-ray experiments led scientists to believe that passage of the x-ray through living tissues could cause damage. "With essentially no dosimetry, patients were exposed sometimes for more than an hour in fluoroscopy and radiography, causing prompt dermatitis and deeper tissue damage" (Rossi & Kellerer, 1995, p. 127). As dental radiography was one of the first experiments, Dr. Otto Walkhoff noticed hair loss on the irradiated side of his dental patients (Sansare, Khanna, & Karjodkar, 2011). In postwar era, "the German school of thought was to deliver massive toxic doses of radiation over a minimal number of treatment fractions, but morbid late effects and poor tumor control led to unease in the radiology community" (Lischalk et al., 2016, p. 731). Dr. Douglas P. Murphy, of the University of Pennsylvania, found that children born after their mother had been treated with x-ray irradiation for growths developed malformations of the head and dwarfed limbs. Additionally, unborn children exposed in the womb had a one in three chance of developing serious conditions (Dangers of X-ray Therapy, 1929). The discovery in the 1960s of the danger of ionizing radiation to the fetus led to the diminished use during pregnancy and the prenatal period.

According to Grigg (as cited by Grey, 2009), in 1904, Clarence Madison Dally, assistant to Thomas Edison, became the first radiation related fatality. X-ray workers noticed that repeated exposures caused skin inflammation, ulcers, sores, superficial and deep cancers, blood abnormalities, and death (Linton, 1995). A number of first generation radiologists, dentists, and technologists were exposed to large amounts of ionizing radiation which resulted in severe radiation injuries (Statkiewicz-Sherer, Visconti, & Ritenour, 1998). Consistent findings in epidemiologic data from 270,000 radiologists and technologists worldwide indicated increased mortality due to leukemia among those who were employed before 1950 (Yoshinaga, Mabuchi, Sigurdson, Doody, & Ron, 2004). Reed (2011) noted, “Today radiation ranks among the most thoroughly investigated causes of disease” (p. 4S).

Before the 1950s, few radiation protection programs had been established. In 1974, the United States Nuclear Regulatory Commission (NRC) was established (Koth & Smith, 2016). The NRC regulates industrial radiography equipment that uses gamma ray sources. Additionally, state regulatory agencies and federal Occupational Safety and Health Administration (OSHA) regulate x-ray machines and accelerators. NRC regulations also require that individuals becoming radiographers receive radiation safety training and pass a licensing exam that includes radiation protection and radiobiology (American Registry of Radiologic Technologists, 2017).

Likewise, the International Commission on Radiological Protection (ICRP) has become the "common basis for radiological protection standards, legislation, guidelines, programmes, and practice" internationally (International Commission on Radiological Protection, n.d., About ICRP, para. 2).

Radiation protection training for radiographers has become standard in programs that educate entry-level radiographers. Accreditation standards mandate that certified radiographers receive instruction including, but not limited to: potential biological effects of ionizing radiation, operational radiation protection, patient and staff radiation protection, typical radiation doses from diagnostic procedures, risks of fetal exposure, and optimization of radiation protection fundamentals (Johnson, 2015).

Specialized modalities have become the replacement for x-rays (Dunn, 2001). Unlike conventional radiography, ultrasonography, computed tomography, and magnetic resonance imaging use cross-sectional imaging techniques to distinguish one organ from another. Additionally, nuclear medicine aids in diagnosis based on the physiologic function of an organ (Long, Rollins, & Smith, 2016). Despite their ability to provide diagnostic images in a noninvasive manner, computed tomography and nuclear medicine expose patients and staff to harmful radiation. Computed tomography is similar to conventional radiography in that it uses ionizing radiation to produce images. Nuclear medicine exposes patients and staff to radiation via intravenously injected radioactive tracers (Long et al., 2016).

Magnetic Resonance Imaging

Although Roentgen's discovery of the x-ray changed the field of medicine, Raymond Damadian observed shortcomings in the technology. A postgraduate student at Harvard University, Damadian was certain magnetic resonance imaging equipment could create contrast between tissue and surrounding tumors, unlike current radiographic technology (Genn, 2003). Developments in cryogenics (the study of very low temperatures) were occurring at the same time and thus made the development of a whole-body superconducting magnet possible (McRobbie, Moore, Graves, & Prince, 2004). Damadian was granted a patent in 1974 to construct the first commercial MRI machine. Damadian and his team of graduate students created "Indomitable," a superconducting magnet with a liquid helium cooling system, an oscilloscope, an antenna coil, and a minicomputer (Genn, 2003). On July 3, 1977, the first images were produced after nearly five hours of scan time and rotating the patient 106 times (Woodward & Freimarck, 1995). Largely inefficient, the first imaging systems were limited to scanning points and lines rather than whole sections of the body.

Whole body scanners operated at 0.04-0.1 Tesla (a unit of magnetic field strength). Damadian pioneered the superconducting MRI scanner which paved the way for the invention of scanners capable of operating at 0.35 Tesla. Today, imaging systems can reach 9 Tesla (Gore, 2003). Current MRI scanners produce 3D images and video of moving organs in 20 minutes due to faster computers, improved hardware, and improved radio frequency antennas (Lakrimi et al.,2012). In 2016, over 39 million MRI scans were performed in the United States and the number of sites performing MRI scans increased to approximately 8,520 (IMV, 2017). Unlike conventional radiography, magnetic resonance imaging "creates images of structures through the interactions of magnetic fields and radio waves with tissues without the use of ionizing radiation" (Long, Rollins, & Smith, 2016, p. 342).

The use of magnetic resonance imaging has expanded in recent years. An increasingly common use is in the field of forensic science. With the ability to examine gunshot wounds, identify accidental injuries, chest trauma, hepatic injuries, severity of strangulation, and proof of child abuse or medical negligence, “MR imaging provide[s] the greatest potential for postmortem information” (Reynolds, 2010, p. 361).

MRI Safety Hazards

Magnetic resonance imaging is considered a safe technology because it does not use ionizing radiation, yet there are “intrinsic hazards that must be understood, acknowledged and taken into consideration” (Shellock & Crues as cited by Hartwig, 2015, p. 681). There are three types of magnetic fields in MRI that can cause potential hazards. The static magnetic field can torque, attract, and accelerate ferromagnetic objects in an MRI scanner causing them to become dangerous projectiles. It can also interfere with implanted devices such as pacemakers and medication pumps. Hazards in the radiofrequency field can result in tissue heating, particularly in the area of an implanted device. In addition, the gradient magnetic field can cause peripheral nerve stimulation, implant heating, and acoustic noise (Sammet, 2016).

Westbrook, Roth, and Talbot (2013) suggest, “The static magnetic field has no respect for the confines of conventional walls, floors or ceilings…It is therefore recommended that the general public (those persons who have not been properly screened for the effects of magnetic fields) remain out of the field strength below 5G [Gauss]” (p. 354, 360). Generally, an MR facility is built so that the static magnetic fringe field drops below 5 Gauss inside the walls of the scan room. In some instances, the facility design allows for the 5 Gauss line to extend beyond the walls of the scan room (Schaap, Christopher-DeVries, Slottje, & Kromhout, 2013). If a large object is attracted to the MR scanner, considerable time and money can be spent dislodging it. Therefore, precautions must be taken to prevent ferromagnetic objects from entering the scan room (Carr & Grey, 2002). Consider housekeeping, for example. A simple act regularly performed throughout the facility can present a challenge in the MRI suite. Due to the magnetic field generated by MRI scanners, "…the MRI suite is regularly the scene of accidents involving undertrained or careless housekeeping staffs with vacuums, floor polishers or mop buckets. While these accidents have not resulted in death, there have been many injuries to cleaning personnel and damage to expensive MRI equipment" (Rozovsky, Gilk, & Latino, 2006, p. 21).

MRI is the most widely used application of high static magnetic fields. Clinical application scanners can have a field strength ranging from 0.15 Tesla to 3 Tesla. Research scanners typically range from 3 to 10 Tesla. Higher field strength scanners yield better signal-to-noise ratios and increased spatial resolution (Yamaguchi-Sekino, Sekino, & Ueno, 2011). However, "The increasing popularity of 3T [Tesla] systems raises the stakes further, as the higher field strength draws metal objects faster with a more powerful impact than if they were drawn into a 1.5T [Tesla] magnet. This increases the potential for serious injury and the cost of repairing the scanner" (Freiherr, 2004, p. 73).

MRI Technologist Training

Eventually, more radiographers transitioned into the specialty of MRI and their safety training shifted from ionizing radiation to magnetic field safety. The American Registry of Radiologic Technologists (ARRT) is the governing body responsible for offering credentials in medical imaging. From 1992-1994, the ARRT initiated a comprehensive job analysis which resulted in the first certification examination in MRI in 1995 (American Registry of Radiologic Technologists as cited by Grey, 2009). Although requirements for becoming an MRI technologist have changed throughout the history of the ARRT, the most recent changes were implemented January 1, 2015. The ARRT offers two pathways to becoming credentialed in MRI, primary and post-primary. Before enrolling in an MRI educational program, candidates for primary pathway certification must complete an associate degree or higher from an institution accredited by the ARRT or ARRT-recognized accreditation agency; the degree does not have to be in radiological sciences. Candidates for post-primary certification will have already earned an associate’s degree or higher and be ARRT credentialed (American Registry of Radiologic Technologists, 2017). During their MRI education, students are required to complete didactic coursework and a designated number and type of clinical procedures. Upon graduation, students are eligible to take the Magnetic Resonance Imaging licensing examination.

“Successful performance of these fundamental [clinical] procedures, in combination with mastery of the cognitive knowledge and skills covered by the MRI examination, provides the basis for acquisition of the full range of clinical skills required in a variety of settings” (American Registry of Radiologic Technology, 2015, p. 1). However, Westbrook (2017) noted that the debate continues regarding the efficacy of formal post-graduate training versus workplace training. Regardless of training method, technologists must submit a specified number of continuing education credits biennially. “The education and training of an MRI Technologist is distinct from any other medical imaging modality. The patient safety issues, especially, are specific to MRI which involves very strong magnetic fields that can affect medically implanted devices” (American Registry of Magnetic Resonance Imaging Technologists, 2016, p. 1). According to Hipp, Sammet, and Strauss (as cited by Sammet, 2016),

> It is also important that radiologists, referring physicians and MR technologists are able to evaluate MRI safety and compatibility of medical devices and implants because they are often the first health care professionals who will talk to a patient about an MRI exam, potential risks, and MRI safety (p. 444).

Annual MRI safety training should include technical and medical background of MRI safety, hands-on demonstrations of missile-effects, detailed screening procedures, burns, acoustic noise levels, and magnetic quench (Sammet, 2016).

The Medicines and Healthcare Products Regulatory Agency (2014) recommends that each organization employing the use of an MR scanner should establish an individual responsible (referred to as the "MR responsible person" or "MR safety officer") for the day-to-day managerial operations to ensure written policies, and operational and emergency procedures are issued to personnel who have access to MR equipment. Furthermore, their responsibility is to inform all department heads and senior medical staff, who may have personnel that will be involved with MRI equipment, of the formal procedures for training and authorization. The MR responsible person should formally approve authorization of a staff member following satisfactory completion of training in their responsibilities and safety requirements of MRI equipment.

Likewise, an MR Safety Expert, typically an MR physicist or an individual with suitable technical MR expertise, should be:

> A designated professional with adequate training, knowledge, and experience of MRI equipment, its uses and associated requirements …. and be in a position to adequately advise on the necessary engineering, scientific and administrative aspects of the safe clinical use of the MR devices including site planning, development of a safety framework, advising on monitoring the effectiveness of local safety procedures, procurement, adverse incident investigation and advising on specific patient examinations. Their knowledge of MR physics should enable them to advise on the risks

> associated with individual procedures and on methods to mitigate these risks (Medicines and Healthcare Products Regulatory Agency, 2014, p. 22).

As MR safety has been brought to the forefront of the rapidly advancing technology, various MR safety certifications have developed for radiologists, technologists, and medical physicists. Upon completion of a specialized training course, candidates are eligible to take a formal MR Safety licensing exam (American Board of Magnetic Resonance Safety, 2017).

Non-MRI Healthcare Provider Training

Similar to MR workers, healthcare and research staff are mainly exposed to the static magnetic field (Hartwig, 2015). Higher acuity patients are being seen more frequently in the MRI department and thus require the support of ancillary staff. In some instances, sedation or anesthesia is required to minimize motion and maximize image quality. “It is important that all personnel associated with the anesthesia of patients for MRI acquire a basic understanding of the technology and a familiarity with patient management considerations to provide a level of anesthesia support equal to any other situation” (Smith, 2010, p. 98). Farling, et al. (2010) suggested:

> It should be recognised that the supervising MR radiographer is responsible operationally for MR safety within the controlled area and anaesthetic staff should defer to him/her in relation to MR safety matters, in particular control of access of staff and equipment into the controlled area (p. 767).

According to Westbrook, Roth, and Talbot (2011), “It has become the accepted standard to provide safety training and education for anyone who could access the MRI scan room” (p. 360). Nurses play a vital role in reducing potential hazards by pre-screening patients before their procedure. “Familiarity with basic principles of [MR] technology, as well as its risks and benefits, is therefore crucial" (Carr & Grey, 2002, p. 26). Although some level of MRI safety training is required for all bed-side caregivers, the amount and quality differs from that of an MRI technologist. Gilk (2007) states, "Though many experienced MR staffers understand the risks, it is likely that the incidental personnel--such as housekeeping, engineering, transport--who may regularly serve the area know little of the breadth of risks to which they may be exposed (or to which they may be exposing others)" (p. 30). According to Kanal et al. (2013),

> All individuals working within at least Zone 3 of the MR environment should be documented as having successfully completed at least one of the MR safety live lectures or prerecorded presentations approved by the MR medical director. Attendance should be repeated at least annually, and appropriate documentation should be provided to confirm these ongoing educational efforts (p. 505).

Staff who work in Zone 3 are grouped into Level 1 or Level 2 personnel. Level 1 consists of individuals who have passed minimal safety training (i.e. nursing, respiratory, transportation, and radiology staff). Level 2 personnel are individuals who have passed extensive safety training (i.e. MRI technologists and radiologists) (Kanal et al., 2013). The most effective way to minimize potential safety hazards is for Level 2 personnel to perform verbal and written screening on all Level 1 personnel every time they enter the scan room (Westbrook, Roth, & Talbot, 2011).

Lack of communication between MRI staff and the clinical team can result in incidents that would otherwise be preventable (Lee, Lin, & Chan, 2015). Use of the aforementioned MR responsible person or safety officer supports operational responsibility through development and enforcement of policies and procedures that minimize risk, manages hazards of MR equipment, and ensures proper education to all staff members who enter the MR environment (Calamante, Ittermann, Kanal, The Inter-Society Working Group on MR Safety, & Norris, 2016).

Summary

Since the discovery of the X-ray in 1895, many advances have been made in the field of medical imaging. Magnetic resonance imaging is one advancement that has benefited patients because it does not require ionizing radiation or harmful contrast agents. However, the MRI suite is not without its own dangers, which can occur due to three different types of magnetic fields. It is imperative that all individuals working in the MRI environment, not just the MRI technologists, receive proper safety training.

CHAPTER 3

METHODOLOGY

Overview

The purpose of this study was to determine the knowledge level of non-MRI healthcare providers regarding safety risks associated with MRI. Additionally, the study was intended to determine the non-MRI healthcare provider's level of satisfaction regarding the MRI safety education training they received. Demographic data was obtained to determine if responses differed based on the participant's length of employment. A quantitative research design using an electronic survey was selected as the methodology.

Research Questions

The following questions were used to guide this study:

1. What is the knowledge level of non-MRI healthcare providers regarding MRI safety?
2. What is the knowledge level of non-MRI healthcare providers regarding safety hazards in MRI?
3. Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?
4. Is there a difference in MRI safety knowledge level among providers based on length of employment?

Research Design

This study used a non-experimental, cross-sectional quantitative design to examine the MRI safety knowledge of non-MRI healthcare providers and their satisfaction regarding the MRI safety training they have received. According to Cottrell and McKenzie (2011), "[non-experimental research] is very important research, often answering important questions for the health education profession" (p. 194). "Cross-sectional studies collect data at one specific point in time. They can be used to determine the current attitudes, opinions, beliefs, values, behaviors, or characteristics of a given population" (Cottrell & McKenzie, 2011, p. 196). Cross-sectional studies are also useful in program evaluation and thus the design was chosen to evaluate participants' satisfaction with their MRI safety training.

Given that the purpose of the study was to determine the knowledge level and satisfaction with MRI safety training, data collected and disseminated may be used to inform health care administrators of any deficiencies in MRI safety training for non-MRI healthcare providers. Furthermore, results of the study may provide information to improve the amount and quality of training provided to non-MRI healthcare providers.

Strengths and Limitations

One strength of using a non-experimental research design is the ability to conduct an online survey in an anonymous and confidential manner and therefore, participants' answers are not influenced by the researcher or other participants. Because all participants were required to answer the same questions, the data collected provided the same feedback regarding the same topic.

A limitation of the design is the dependence upon enough participants to ensure validity.

Population

This study's population included registered nurses, licensed practical nurses, certified nursing assistants, certified nurse anesthetists, surgical technologists, radiologic technologists, and respiratory therapists within Mission Health System, a six-hospital health system in Asheville, North Carolina ranging in size from 50 to 800 beds and Caromont Regional Medical Center, a single 435 bed facility located in Gastonia, North Carolina.

The population in this study was chosen because their assistance is often required in the MRI suite to accomplish imaging on pediatric, sedated, or critically ill patients.

Survey Instrument Development

After an extensive review of the available literature, it was determined that there is not a survey instrument suitable for this project. Using information from the literature review, the researcher developed the survey instrument to gather information which would assess MRI safety knowledge and satisfaction levels of current MRI safety training.

The first four questions solicited demographic information. They were also used to answer the research question “Is there a difference in MRI safety knowledge level among providers based on length of employment?” Questions 6-17 were used to answer the research question “What is the knowledge level of non-MRI healthcare providers regarding MRI safety?” Question 18, a three-part question, was used to answer the research question “Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?”

The survey instrument was created and deployed using Survey Monkey, a commercial online survey platform. An online survey was of benefit in reaching a broader group of participants as it included employees who are located at satellite facilities. Furthermore, this method provided participants a more convenient option of completing the survey at any time during the data collection period. Web-based survey methods have become the method of choice for some researchers because they are acceptable to institutional review boards, have reduced response time, reduced cost of materials, and allow flexibility in design and format of the survey. Another advantage of web-based surveys is the ease of data collection. Responses can be formatted for entry into a statistical data package, eliminating manual data entry (Cottrell & McKenzie, 2011; Evans et al., 2009).

Although the response rate for web-based surveys can vary according to different studies, there are steps that can be taken to improve response rate. These measures include creating a well-defined survey instrument, financial incentives, and repeated contacts to participants who do not respond (Cottrell & McKenzie, 2011).

Instrument Validity

A pilot survey [Appendix A] was used to establish the validity of the survey instrument. According to Cottrell and McKenzie (2011), "using a valid instrument increases the chance that researchers are measuring what they want to measure, thus ruling out other possible explanations for their findings" (p. 149).

Ten peers in targeted allied health professions (nursing, radiography, and respiratory therapy) in Western North Carolina and Eastern Tennessee participated in the pilot study. Those participating in the pilot were given a cover letter [Appendix B] explaining why they were chosen and instructions for completing the survey. The pilot study participants completed a survey assessment tool [Appendix C] to assess survey validity. Pilot study participants were asked to evaluate each question for clarity and relevance. In addition, they were requested to make recommendations on each question and on the overall survey instrument. Upon recommendation, two questions were omitted, one profession was replaced, and several grammatical revisions were made to clarify the questions. After the necessary revisions, a final draft was submitted for approval by the Institutional Boards of Mission Health, Caromont Health, and East Tennessee State University.

Informed Consent Consideration

All participants received a cover letter [Appendix D] and informed consent [Appendix E]. This communication provided a description of the study, statement of confidentiality of the responses, and a request for confirmation of their consent to participate in the study. Participation in the study by completing the survey served as indication of consent.

The researcher requested a waiver for documenting consent because the only identifiable information linking the participants to the study is the consent form.

Data Collection Procedures

Participants were solicited through their employer email and connected to an online survey [Appendix F] through a web link provided in the email.

Data collection began with a notification email inviting participation on Tuesday, September 11, 2018. On Tuesday, September 18, 2018 a follow-up email reminder was sent to all participants. Data collection closed on Wednesday, September 26, 2018.

To ensure that participants only completed the survey once, the “multiple response” feature in Survey Monkey was turned off so that only one response per email address was allowed.

Data Analysis

The researcher exported the data from Survey Monkey and converted it into a Statistical Package for the Social Sciences (SPSS) format. Statistical Package for the Social Sciences (SPSS) Version 24 was used for the analysis. A simple analysis of variance (ANOVA) test was used.

Question 1 asked respondents to agree to participate in the study. Questions 2-5 solicited demographic information from the participant’s profession and responses were reported using descriptive statistics. Additionally, these questions were used to answer the research question “Is there a difference in MRI safety knowledge level among providers based on length of employment?” Questions 6-17 were used to answer the research question “What is the knowledge level of non-MRI healthcare providers regarding MRI safety?” Data was reported using descriptive statistics and a one-way ANOVA was used to determine differences based on select demographic variables. Question 18, a three-part question, was used to answer the research question “Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?” Data was reported using descriptive statistics and a one-way ANOVA was used to determine differences based on select demographic variables.

Summary

This chapter contained information regarding the research design for this study. Survey development, including pilot study and instrument validity, were discussed in detail. The proposed population and providing informed consent were also discussed. Data collection procedures and analysis was provided in detail.

CHAPTER 4

PRESENTATION AND ANALYSIS OF THE DATA

The purpose of this study was to determine the knowledge level of non-MRI healthcare providers regarding safety risks associated with MRI technology. Additionally, the study determined the non-MRI healthcare provider's level of satisfaction regarding MRI safety education training they received.

This study used a non-experimental, cross-sectional quantitative design to examine the MRI safety knowledge of non-MRI healthcare providers and their satisfaction regarding the MRI safety training they received. Given that the purpose of the study was to determine the knowledge level and satisfaction with MRI safety training, data collected and disseminated may be used to inform health care administrators of any deficiencies in MRI safety training for non-MRI healthcare providers. Results of the study may provide information to improve the training provided to non-MRI healthcare providers.

The following questions guided this research:

1. What is the knowledge level of non-MRI healthcare providers regarding MRI safety?
2. What is the knowledge level of non-MRI healthcare providers regarding safety hazards in MRI?
3. Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?
4. Is there a difference in MRI safety knowledge level among providers based on length of employment?

Respondents

A total of 267 nursing and allied health professionals accessed the survey, however, only 225 responses were usable for this study. Thirty-nine respondents had incomplete surveys and three respondents did not agree to participate in the study.

Of the respondents, 117 were from Caromont Health System and 105 were from Mission Health System; three respondents did not indicate with which system they were employed (Table 1).

Table 1

Health Systems

		Frequency	Percent	Valid Percent	Cumulative Percent
	Mission Health	105	46.7	47.3	47.3
	Caromont Health	117	52.0	52.7	100.0
	Total	222	98.7	100.0	
	No indication	3	1.3		
Total		225	100.0		

Among those responding, there were 14 certified nursing assistants, 24 certified registered nurse anesthetists, 31 radiologic technologists, 142 registered nurses, and 7 respiratory therapists. Seven respondents did not indicate their professions. There were no certified medical assistants, licensed practical nurses, or surgical technologist respondents from either health system who participated in the study (Table 2).

Table 2

Profession

	Frequency	Percent	Valid percent	Cumulative percent
CNA	14	6.2	6.3	6.3
CRNA	24	10.7	10.7	17.0
Radiography Tech	31	13.8	13.8	30.8
RN	142	63.1	63.4	94.2
Respiratory Therapist	7	3.1	3.1	97.3
Did not indicate profession	7	3.1	3.1	100
Total	225	100.0		

Of the respondents from Mission Health System, 11 were certified nursing assistants, 20 were certified registered nurse anesthetists, 73 were registered nurses, and 7 were respiratory therapists. No certified medical assistants, licensed practical nurses, radiologic technologists, surgical technologists responded from Mission Health System. Of the respondents from Caromont Health System, three were certified nursing assistants, four were certified registered nurse anesthetists, 31 were radiologic technologists, and 67 were registered nurses. No certified medical assistants, licensed practical nurses, surgical technologists, or respiratory therapists responded from Caromont.

Research Question 1: What is the knowledge level of non-MRI healthcare providers regarding MRI safety?

Responses to questions 6-17 provided the data for this research question. A traditional 100-point scale was used for grading. Collectively, on a 100-point scale the mean, median, and mode were 50.47, 50.04, 47.26, respectively.

The mean scores for each profession were CNA 50.79; CRNA 50.77; radiography technologists 50.14; RN 50.39; and respiratory therapists 52.6.

Research Question 2: What is the knowledge level of non-MRI healthcare providers regarding safety hazards in MRI?

Responses to questions 6, 9, 10, 12, and 13 provided the data for this research question. Question 6 asked respondents to rank three metal objects according to their safety hazard when exposed to a magnetic field. The items included a paper clip in the shirt pocket of an employee at the MRI bedside, silver earrings worn by an employee at the MRI bedside, and a non-MRI wheelchair at the doorway to the MRI scan room. The correct rank order for these objects was: a paper clip in the shirt pocket of an employee at the MRI bedside, a non-MRI wheelchair at the doorway to the MRI scan room, and silver earrings worn by an employee at the MRI bedside. Sixty-three percent (63%) of the respondents (n=140) ranked a non-MRI wheelchair in the doorway as having the most hazardous potential. Some respondents did not rank all the items. Of those who did, only 57 of the respondents (26%) answered correctly and ranked a paperclip in an employee's shirt pocket at the MRI bedside as posing the most danger.

Question 9 asked respondents to indicate how far the magnetic field extends beyond the MRI scanner. One hundred twenty-two respondents (55%) chose the correct answer of 20 feet.

Eighty-eight respondents (40%) chose 5 feet and 12 respondents (5%) chose the magnetic field is contained to the MRI scanner.

Question 10 asked respondents when the magnetic field is turned off. The response options were 1) when the power supply is cut off to the machine (i.e. power outage), 2) when the scanner is not in use (between patients or when staff leave at night), or 3) never. The correct answer is never. One hundred fifty-eight respondents (70.5%) chose “never” as the correct answer.

Question 12 gave respondents a list of three possible dangers that can occur with exposure to a magnetic field and asked them to choose the items they thought were dangerous. All answer choices, torque or migration of an implant, tissue overheating, and dizziness or nausea can occur with magnetic field exposure should have been selected. Only 40 respondents (18%) chose all three answers and ninety-nine respondents (44%) chose two out of three as possible dangers. The most frequently chosen answer (98%) was torque or migration of an implant. Dizziness and nausea was the second most frequently chosen answer (46%) and tissue overheating was chosen least frequently (35%).

Question 13 asked respondents to choose how many safety zones there are in a typical MRI department, two, four, or six. The correct answer is four. One hundred forty respondents (63%) chose the correct answer of four zones.

Research Question 3: Are non-MRI healthcare providers satisfied with the MRI safety education training they receive?

Responses to question 18 provided the data for this research question. Using a Likert-type scale, respondents indicated whether their current safety education training is adequate for them to safely perform their job in MRI, whether they would like additional training, and whether annual training is frequent enough.

Fourteen respondents (6.2%) strongly disagreed and 42 respondents (18.7%) disagreed that their MRI safety training was adequate. Conversely, 135 respondents (60%) agreed and 33 (14.7%) strongly agreed. The results in Table 3 indicate that most employees believe they are receiving enough MRI safety training to help them safely perform their job duties while in the MRI department.

Table 3

Adequate Training

		Frequency	Percent	Valid Percent	Cumulative Percent
	Strongly Disagree	14	6.2	6.3	6.3
	Disagree	42	18.7	18.8	25.0
	Agree	135	60.0	60.3	85.3
	Strongly Agree	33	14.7	14.7	100.0
	Total	224	99.6	100.0	
	No response	1	.4		
Total		225	100.0		

When asked if they would like more MRI safety training, eight respondents (3.6%) strongly disagreed and 75 respondents (33.3%) disagreed that they would like additional training. However, 105 (46.7%) agreed, and 28 (12.4%) strongly agreed (See Table 4).

Table 4

Wants More Training

		Frequency	Percent	Valid Percent	Cumulative Percent
	Strongly Disagree	8	3.6	3.6	3.6
	Disagree	75	33.3	33.5	37.1
	Agree	105	46.7	46.9	83.9
	Strongly Agree	28	12.4	12.5	96.4
	99	8	3.6	3.6	100.0
	Total	224	99.6	100.0	
	No response	1	.4		
Total		225	100.0		

The final question in the category asked respondents if annual training is enough. Three respondents (1.3%) strongly disagreed, 41 (18.2%) disagreed, 137 (60.9%) agreed, and 39 (17.3%) strongly agreed. Results, displayed in Table 5, indicate that an overwhelming number of respondents are content with completing MRI safety training once per year.

Table 5

Once Yearly is Enough Training

		Frequency	Percent	Valid Percent	Cumulative Percent
	Strongly Disagree	3	1.3	1.3	1.3
	Disagree	41	18.2	18.3	19.6
	Agree	137	60.9	61.2	80.8
	Strongly Agree	39	17.3	17.4	98.2
	99	4	1.8	1.8	100.0
	Total	224	99.6	100.0	
	No response	1	.4		
Total		225	100.0		

The data indicated most employees are satisfied with the frequency of their training. However, almost 60% would like more detailed training.

Research Question 4: Is there a difference in MRI safety knowledge level among providers based on length of employment?

Questions 2-5 solicited demographic data and questions 6-17 were used as knowledge-based questions. Knowledge-based questions were graded on a 100-point scale and compared to demographic information to provide data for this research question. Demographic data included the participant's profession and their length of employment (Table 6) in the profession.

Table 6

Length of Employment

		Frequency	Percent	Valid Percent	Cumulative Percent
	Less than 1 year	18	8.0	8.0	8.0
	1 to 2 years	31	13.8	13.8	21.9
	3 to 5 years	34	15.1	15.2	37.1
	6 to 10 years	37	16.4	16.5	53.6
	More than 10 years	104	46.2	46.4	100.0
	Total	224	99.6	100.0	
	No response	1	.4		
Total		225	100.0		

Of the 18 respondents scoring above 70 on the graded questions, eight (44%) were employed in their profession more than 10 years. Four respondents (22%) were employed 6-10 years; three respondents (17%) were employed 3-5 years; and three respondents (17%) were employed 1-2 years. No respondents employed in their profession less than a year scored over a 70.

A one-way analysis of variance (ANOVA) was conducted to determine if differences existed in knowledge as measured by test scores derived from questions 6-17 based on length of employment. The factor variable, length of employment, included five categories: less than one year, one to two years, three to five years, six to 10 years, more than 10 years. The outcome variable was MRI safety knowledge level. At a 95% confidence interval (alpha=.05), no significant difference was found based upon length of employment (p=.338).

CHAPTER 5

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

The purpose of this study was to determine the knowledge level of non-MRI healthcare providers regarding safety risks associated with MRI technology. Additionally, the study determined the non-MRI healthcare provider's level of satisfaction regarding the MRI safety education training they received.

I developed an MRI safety questionnaire, as described in Chapter 3, as the survey instrument for this study. A link to the online survey was distributed to participants by their department supervisors or educators. A total of two-hundred twenty-five (225) respondents completed the survey.

Conclusions

The limitations of this study must be considered when compiling conclusions. This study was limited to non-MRI healthcare providers across two inpatient North Carolina health systems in September of 2018.

Based on results of the study, I drew the following conclusions regarding MRI safety knowledge and the level of satisfaction regarding MRI safety education training:

1. Non-MRI providers were knowledgeable in the safety aspects of the most common unsafe or conditional objects, and the general features of an MRI scanner (i.e. the magnet is always on and the distance of the fringe field).

2. Non-MRI healthcare providers are knowledgeable about the safety risk of common unsafe objects, which have been widely publicized in the healthcare setting as hazardous in the MRI suite.

2. Non-MRI healthcare providers were satisfied with completing safety training on an annual basis however, they would like more detailed training.

3. Length of employment in a profession did not impact MRI safety knowledge.

Discussion

Non-MRI healthcare providers are well educated on the safety hazards of the most common ferromagnetic objects, such as wheelchairs, oxygen tanks, transport stretchers, and patient beds. Many small items are overlooked but often pose a safety threat to anyone in the path of trajectory. For example, participants were asked to rank three metal objects according to the risk they pose: a paper clip in the shirt pocket of an employee at the MRI bedside, silver earrings worn by an employee at the MRI bedside, and a non-MRI wheelchair at the doorway to the MRI scan room. The object ranked most hazardous was the non-MRI wheelchair in the doorway of the scan room. While a ferrous wheelchair does have strong potential to pose hazardous or even fatal injuries, a paperclip can travel 40 miles per hour when exposed to a magnetic field. The velocity of the paperclip poses the threat of injury, particularly to the eye. According to Westbrook, Roth, and Talbot (2011), the projectile force of an object is based on mass of the object, ferromagnetic properties, magnetic field strength, and distance from the magnet. Therefore, a paperclip can pose an equal hazard when placed close to the magnet.

I was not surprised that non-MRI healthcare providers are being well educated on the "big ticket" items, such as non-MRI wheelchairs and stretchers but are not receiving the same amount of education regarding smaller items which can pose a severe safety threat.

A majority of respondents were knowledgeable about how far the magnetic field extends beyond the MRI scanner, how many safety zones are in the department, and that the magnet is never turned off.

I believe that signage indicating safety zones, gauss lines, and the "Magnet is always on" could have attributed to an increased number of participants choosing the correct answer.

According to Kanal et al., (2013), zones 3 and 4 should be clearly demarcated and “signage should inform the public that the magnetic field is active even when power to the facility is deactivated” (p. 504).

Participants were somewhat knowledgeable regarding three possible dangers that can occur with magnetic field exposure, torque or migration of an implant, tissue overheating, and dizziness or nausea. All three answers should have been chosen but only 40 respondents (18%) chose all three. I was not surprised by the answers chosen by respondents because the MRI safety education most non-MRI healthcare providers receive is concentrated on the strength and force of the magnetic field. While this is important, the additional biological effects of magnetic field exposure should not be overlooked.

An overwhelming majority of respondents felt their current safety education training is adequate for them to safely perform their job in MRI and are content with completing MRI safety training only once per year. I expected that most respondents would indicate their training is satisfactory because most MRI safety programs are designed to provide employees with a good base knowledge of MRI safety. Furthermore, most healthcare employees are inundated with annual learning modules and they would prefer not to add additional training. At least half of the respondents indicated that they would like more training. Although increased frequency may not be necessary, more in-depth training could be implemented into the current annual education.

Respondents were asked to place themselves in one of five categories based on length of employment in their profession. An ANOVA test was performed to compare length of employment and MRI safety knowledge level. The findings were not significant to indicate that length of employment in a profession had an impact on MRI safety knowledge.

Recommendations for Practice

The results of this study reflect that non-MRI healthcare providers are knowledgeable in the most common safety aspects of MRI; however, their training should be updated to include more in-depth information on items not commonly reviewed. These topics include small ferrous objects that pose equal hazard (e.g. paper clips, bobby pins in the hair) and biological effects of implants, such as overheating and induced currents.

Additionally, respondents indicated that they would like more training but not necessarily an increased frequency in training. Educators should consider maintaining their annually scheduled training but increase the detail of material provided.

Recommendations for Future Research

Future research studies could add more to the literature on this topic. A similar study should be conducted in a manner that allows the researcher to directly notify participants of the survey. Participants of this study were notified of the survey via their direct supervisor or department educator. This method kept the participants as anonymous as possible but required sole dependence on someone other than the researcher to solicit participation. In a future study, the researcher could conduct the survey at their place of employment, where employees can be contacted directly by the researcher, or obtain email addresses through a different means. Alternatively, the researcher could obtain mailing addresses for the targeted participants and solicit their participation directly through a mass mailing.

This study was conducted in two hospitals in a limited geographic area and may not be indicative of responses in other areas of the country. I would suggest future study to collect data from more than two health systems to provide a broader range of participation. More than eight professions should be chosen for a future study. Additional categories could include environmental service, maintenance, and transport technicians. All of these employees provide some level of service to the MRI department and are required to complete annual MRI safety training.

A future researcher may want to determine if there is a difference in MRI safety knowledge level based on number of visits per month to the MRI department.

Summary

Safety in the MRI department differs from any other department of a healthcare facility. Due to a strong magnetic field, many common objects used in healthcare can pose a hazard to the patient or staff. Therefore, any non-MRI healthcare provider that enters the MRI department should be educated in MRI safety. The typical practice in healthcare facilities is completing an annual learning module specific to MRI safety.

Based on the results of this study, it can be concluded that non-MRI healthcare providers are knowledgeable about most of the safety hazards. They are satisfied with annual training but would like more in-depth material added to their current learning modules. Increasing the awareness of the dangers associated with an MRI scanner will provide a safer environment for all individuals responsible for patients receiving an MRI.

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APPENDICES

Appendix A

Pilot Survey

Please answer each question to the best of your knowledge and provide only one answer for each question.

1. Department/Unit where you work more than 50% of the time:

- ☐ General Medicine Floor
- ☐ Intensive Care Unit
- ☐ Emergency Room
- ☐ Anesthesia/Operating Room
- ☐ Radiology

2. Title of your profession:

- ☐ Registered Nurse
- ☐ Respiratory Therapist
- ☐ Certified Nursing Assistant
- ☐ Emergency Room Technician
- ☐ Radiologic Technologist
- ☐ Certified Nurse Anesthetist
- ☐ Anesthesia Technician

3. How long have you been employed in your profession?

- ☐ Less than 1 year
- ☐ 1-2 years
- ☐ 3-5 years
- ☐ 6-10 years
- ☐ More than 10 years

4. How many times per month would you estimate that you visit the MRI department?

- ☐ 0-1 visits per month
- ☐ 2-4 visits per month
- ☐ 5 or more visits per month

5. What is one reason cell phones and pagers are prohibited in the MRI scan room?

- ☐ They are a distraction from patient care
- ☐ All data on the device could be erased
- ☐ The battery could be depleted

6. What type of radiation does MRI use?

- ☐ Ionizing (x-ray radiation)
- ☐ Electromagnetic
- ☐ There is no radiation in MRI

7. How far does the magnetic field extend beyond the MRI scanner?

- ☐ 5 feet
- ☐ 20 feet
- ☐ It is contained to the MRI scanner

8. The magnetic field is off:

- ☐ When the power supply is cut off (i.e. power outage)
- ☐ When it is not in use (i.e. in between patients or at night when staff turn the scanner off)
- ☐ Never

9. Nicotine patches with an aluminum foil component should be removed before an MRI scan:

- ☐ Because the magnetic field could attract the aluminum foil, pulling it off of the patient
- ☐ Nicotine patches do not need to be removed because aluminum is not attracted to a magnet
- ☐ Because the aluminum foil can heat up and cause a skin burn

10. Possible dangers in the MRI scan room include (circle all that apply):

- ☐ Torque or migration of an implanted device
- ☐ The individual undergoing an MRI can overheat
- ☐ Dizziness or nausea can occur from exposure to the magnetic field

11. There are ______ safety zones in a typical MRI department

- ☐ 4
- ☐ 6
- ☐ 2

12. In addition to the patient themselves, MRI safety screening questions can be completed by the following (choose all that apply):

- ☐ The patient’s family, guardian or healthcare power of attorney
- ☐ The attending or ordering physician
- ☐ The patient’s Registered Nurse

13. The MRI anesthesia cart is needed for an exam this afternoon. The cart has been stored in the anesthesia department since the last time it was used in MRI. Therefore, it is safe to take the cart into the MRI room because:

- ☐ The cart has been properly stored in the anesthesia department
- ☐ It is not safe because the oxygen tank could have been exchanged for a ferrous tank
- ☐ The CRNA from night shift has verified the safety of the cart

14. A 1.5 Tesla MRI system is _____ times the force of the earth’s magnetic field

- ☐ 10,000
- ☐ 17,000
- ☐ 60,000

15. During a medical emergency in the MRI room, the first thing employees should do is:

- ☐ Call a Code Blue, then start CPR
- ☐ Remove the patient from the scan room and call a Code Blue
- ☐ Start CPR, then call a Code Blue

	Strongly Disagree	Disagree	Agree	Strongly Agree

16. I feel that the amount of MRI safety education I receive provides me with enough knowledge to safely perform my job in the MRI scan room	1	2	3	4
17. Sometimes I feel uncomfortable in the MRI scan room because I do not know enough about the strong magnet I am working around	1	2	3	4
18. I would like more in-depth training on MRI safety	1	2	3	4
19. I feel that completing MRI training once a year is sufficient	1	2	3	4

Thank you for taking the time to participate in this study. Your participation is greatly appreciated.

Appendix B

Pilot Study Cover Letter

Dear Participant,

I am a graduate student at East Tennessee State University, a doctoral research university located in Johnson City, TN. I am pursuing a Master of Science in Allied Health and conducting research for my thesis and would greatly appreciate your participation in my pilot study.

Various healthcare professionals are required to assist with patient care in the MRI suite. Regardless of the frequency of visits to the MRI department, it is imperative that anyone assisting in the department have some knowledge of MRI safety. The purpose of this study is to assess the MRI safety knowledge base of non-MRI healthcare personnel as well as their satisfaction with the amount and quality of MRI safety training.

You have been chosen to participate in this pilot study because of your profession and/or knowledge of the subject. I request that you review each question carefully and recommend any changes that should occur before I administer the actual survey. I have attached a short questionnaire to the survey and a space for recommendations. You may return it via email to housert1@etsu.edu

Thank you for your time and assistance in helping develop my survey that will acquire much needed information that may ultimately result in higher quality MRI safety training, thus reducing injuries to patients and staff.

Sincerely,

Tiffany Houser, BSAH, RT(R)(MR)(ARRT)

Housert1@etsu.edu

Appendix C

Survey Assessment Tool

MRI Safety Survey Pilot Study Recommendations

Question number	Is this question clearly worded/easy to understand ? Yes or No	Is this question relevant for non-MRI healthcare professionals? Yes or No	Suggested changes to this question (note: you may also write on the survey itself)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

11			
12			
13			
14			
15			
16			
17			
18			

How long did it take you to complete the pilot survey? ____

Please make any suggestions or commendations below:

Appendix D

Participant Cover Letter

Dear Participant,

I am a student at East Tennessee State University pursuing a Master of Science in Allied Health degree. I am conducting a research study and would greatly appreciate your help in completing this voluntary survey.

You have been chosen for this survey because your skills as an allied health professional are often required for assistance in the MRI environment. Regardless of the frequency of visits to the MRI department, it is imperative that anyone assisting in the department have some knowledge of MRI safety. The purpose of this study is to assess the MRI safety knowledge base of non-MRI healthcare personnel as well as their satisfaction with the amount and quality of MRI safety training.

Your participation in this study is voluntary and has no bearing on your employment or status as a healthcare professional. If you choose not to participate in the survey, you may do so without penalty.

Although there may not be an immediate benefit to you, your participation will provide much needed information that may result in higher quality MRI safety training, thus reducing injuries to staff and patients. As a representative of the MRI community, I can assure you that our goal is to provide a safe environment for all individuals in the MRI suite and part of that goal is insure that non-MRI staff members are appropriately equipped to safely perform their tasks while in the department.

There have been no potential risks identified with this study. Your confidentiality will be protected because no identifying information or personal health information is being collected. If you have questions or concerns about the study, please feel free to contact me at houser1@etsu.edu

Thank you for your participation in this study.

Sincerely,

Tiffany Houser

Appendix E

Informed Consent Form

Consent to Participate in a Research Study

Protocol Title: Assessment of Magnetic Resonance Imaging Safety: Allied Health Professional Clinical Competence

Researcher Name and Contact Information: Tiffany Houser, housert1@etsu.edu

What is the study about and why are you doing it?
This research is being conducted to obtain data regarding the knowledge level of non-MRI healthcare personnel and their satisfaction level of amount and quality of MRI safety education training that they receive.

What are you asking me to do if I agree to be in the study?
If you agree to participate in the study, demographic information will be collected at the beginning of the session. You will be answering a series of general questions related to your knowledge of MRI safety and your satisfaction level regarding amount and quality of MRI safety education. The total time needed to complete the survey is under 15 minutes.

How will this study help me?
The information obtained from this study may help you or others by making recommendations of how to increase the knowledge level and comfort level for non-MRI employees required to visit MRI.

Are there any risks involved with being in the study?
There are no anticipated risks or harms to you as a result of your participation in the study. Participation in the study will be kept confidential and will not affect employment status in any way.

What steps have been taken to minimize participant risk?
The information that you provide will be kept confidential. Only the researcher will have access to the data collected in this study and no identifying information will be shared. No one will be notified about your participation in this study.

Will it cost anything to participate?
No.

What else do I need to know?
Your decision to participate in this study is voluntary. If at any time during this study you wish not to participate, you may do so without any consequence.

Whom can I contact with questions or concerns?
If you have questions, please contact Tiffany Houser at (828) 231-4190. If you have concerns about the study, please contact the East Tennessee State Institutional Review Board (423) 439-6054; Caromont Health Institutional Review Board (704) 834-2786; Mission Health Institutional Review Board (828) 213-1105.

Participant's Agreement: I have read the above information. The study has been explained to me and any questions have been answered. I voluntarily agree to be in this study.

Appendix F

MRI Safety Survey

Please answer each question to the best of your knowledge and provide only one answer for each question, unless indicated.

1. Clicking the agree button indicates that I agree to participate, and I am at least 18 years old.

- ☐ Agree
- ☐ Disagree

2. With which health system are you employed?

- ☐ Caromont Health
- ☐ Mission Health

3. Title of your profession:

- ☐ Certified Medical Assistant
- ☐ Certified Nursing Assistant
- ☐ Certified Registered Nurse Anesthetist
- ☐ Licensed Practical Nurse
- ☐ Radiologic Technologist
- ☐ Registered Nurse
- ☐ Respiratory Therapist
- ☐ Surgical Technologist

4. How long have you been employed in your profession?

- ☐ Less than 1 year
- ☐ 1-2 years
- ☐ 3-5 years
- ☐ 6-10 years
- ☐ More than 10 years

5. In your profession, how many times per month would you estimate that you enter the MRI department?

- ☐ 0-1 visits per month
- ☐ 2-4 visits per month
- ☐ 5 or more visits per month

6. Rate these objects in the order you think they are most likely to be attracted to the MRI machine.

- ☐ A paper clip in the shirt pocket of an employee at the MRI bedside
- ☐ Silver earrings worn by an employee who is standing at the MRI bedside
- ☐ A non-MRI wheelchair brought into the scan room doorway

7. What is the **main** reason cell phones are prohibited in the MRI scan room?

- ☐ They are a distraction from patient care
- ☐ All data on the device could be erased
- ☐ The battery could be depleted

8. What type of radiation does MRI use?

- ☐ Ionizing radiation
- ☐ Non-ionizing radiation
- ☐ There is no radiation in MRI

9. How far does the magnetic field extend beyond the MRI scanner?

- ☐ 5 feet
- ☐ 20 feet
- ☐ It is contained to the MRI scanner

10. The magnetic field is off:

- ☐ When the power supply is cut off (i.e. power outage)
- ☐ When it is not in use (i.e. in between patients or at night when staff turn the scanner off)
- ☐ Never

11. Why should nicotine patches with an aluminum foil component be removed before the patient undergoes an MRI scan?

- ☐ The magnetic field could attract the aluminum foil, pulling it off of the patient
- ☐ Nicotine patches do not need to be removed because aluminum is not attracted to a magnet
- ☐ The aluminum foil can heat up and cause a skin burn

12. Possible dangers in the MRI scan room include (select all that apply):

- ☐ Torque or migration of an implanted device
- ☐ The individual undergoing an MRI can overheat
- ☐ Dizziness or nausea can occur from exposure to the magnetic field

13. There are ______ safety zones in a typical MRI department

- ☐ 2
- ☐ 4
- ☐ 6

14. In addition to the patient themselves, MRI safety screening questions can be completed by the following (select all that apply):

- ☐ The patient’s family, guardian or healthcare power of attorney
- ☐ The attending or ordering physician
- ☐ The patient’s Registered Nurse

15. The MRI anesthesia cart is needed for an exam this afternoon. The cart has been stored in the anesthesia department since the last time it was used in MRI. Why is it safe to take the cart into the MRI room?

- ☐ The cart has been properly stored in the anesthesia department
- ☐ It is not safe because the oxygen tank could have been exchanged for a ferrous tank
- ☐ The Certified Registered Nurse Anesthetist from night shift has verified the safety of the cart

16. A 1.5 Tesla MRI system is _____ times the force of the earth’s magnetic field

- ☐ 10,000
- ☐ 17,000
- ☐ 60,000

17. During a medical emergency in the MRI room, the first thing employees should do is:

- ☐ Call a Code Blue while starting CPR
- ☐ Remove the patient from the scan room and call a Code Blue
- ☐ Move the patient from the MRI table to a stretcher and start CPR

	Strongly Disagree	Disagree	Agree	Strongly Agree
18. The MRI safety education I receive is adequate for me to safely perform my job in the MRI scan room	1	2	3	4
I would like more training on MRI safety	1	2	3	4

Completing MRI training once a year is sufficient	1	2	3	4

Thank you for taking the time to participate in this study. Your participation is greatly appreciated.

VITA

TIFFANY HOUSER

Education:	Master of Science, Allied Health, 2019, East Tennessee State University, Johnson City, TN
	Bachelor of Science, Allied Health, 2015, East Tennessee State University, Johnson City, TN
	Associate in Applied Science in Radiography, 1999, Asheville-Buncombe Technical Community College, Asheville, NC
Professional Experience:	MRI & Radiography Instructor, Cleveland Community College, Shelby, NC, 2017-present
	Staff MRI Technologist, Mission Health, Asheville, NC, 2001-2017
	Staff Radiography Technologist, Asheville Radiology Associates, Asheville, NC, 1999-2001
Honors and Awards:	Graduated Magna Cum Laude, 2015
	Recipient of Deans List Award, 2014